TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 59.

THE DYNAMOMETER HUB FOR TESTING PROPELLERS AND ENGINES DURING FLIGHT.

By

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July, 1921.

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The need for a "FLYING-TEST BENCH" to enable measurements of flight resistance, engine and propeller power and efficiency to be made during flight was experienced in interested circles as early as 1915, and it grew in proportion to the constant demand for increased flying capacity in our military types of aircraft.

The problem was worked out in various ways by the German Aeronautical Laboratory (D.V.L.) at Adlershof. Unlike the method observed in the actual flying test-bench, where the engine must be so installed that it can work freely, a DYNAMOMETER HUB" was inserted between the engine and the propeller by the D.V.L. It was approved of as an accurate measuring device by the Propeller Testing Department of the Technical Section of Aviation (Flz.) at Adlershof, and was accordingly constructed there. Measurements of stress are also taken in this case by manometrical pistons constructed by the D.V.L. in accordance with the patent taken out by Professor BENDEMANN, who readily consented

* From "Zeitschrift für Flugtechnik und Motorluftschiffahrt," Vol. X, No.19.

to its being utilized by the D.V.L. The Flz. developed the device into a thrust-dynamometer only - its original purpose was that of measuring propeller thrust - while a still newer type rendered it possible to measure torque moment also. After favorable test-bench results had been obtained, the first flight tests were made with the dynamometer hub in the spring of 1917, and further good results were obtained in numerous flights. The efficiency of the engine could, however, be determined by the transposition of calculations of its power at the test-bench. It would take up too much space to give a detailed account of the tests, which are but of minor importance.

The device constructed by W. STIEBER, of the D.V.L., fulfilled the requirements of a torque measuring apparatus from the outset. The construction and working of this hub were fully described in "Technische Berichte," Vol. III, No.6, p.221, from which we quote the following main points:

The propeller is not rigidly secured to the engine cone, but is free to revolve or to move towards the cone. The transmission of torque from the engine to the propeller, and the transmission of thrust from the propeller to the engine takes place through dynamometrical pistons by which both torque and thrust may be measured. The dynamometer hub consists of three principal parts (see Figs. 4, 5, 6, and 7);

The cone a is secured to the engine shaft in the usual way, by a tightening nut e. The hub-piece h, to which the propeller is fastened by a flange and a bolt, is located on the cylindrical surface of the cone and is free to revolve or to be displaced. The support u for the cylinder is securely attached to the cone a by a toothed coupling d. Four pistons are located in this support, two of which are at a tangent for transmission of the propeller torque, and two parallel to the axis to receive the thrust. Between the pistons and the hub-piece, and in order to ensure their freedom to move on the cone, rams are inserted, which revolve on pivots. The pistons are tightly ground into the cylinders (see Figs. 5 & 11). There is a pressure liquid in the interior of these cylinders - oil in the present instance - and the pressure of this oil corresponds to the pressure on the outside of the piston caused by the action of the valve control, which consists of a distribution piston axially connected with the main piston. The portion of the distribution piston fitting into the cylinder bore is finished off in triangular form and the small end of it, which projects out of the bore into a small pressure space, is again ground into perfect cylinder form.

Bores connect the inside of the cylinders with this pressure space, and the triangular portion of the distribution cylinder is directly connected with the high pressure oil. The working is such that when the forces inside and outside the piston are in equilibrium, the high pressure oil is cut off from the interior of the cylinder through the distribution piston. When oil escapes through lack of tautness, the main piston and consequently the distribution piston fall in, to some extent, leaving the communication between the triangular space of the distribution piston and the inside of the cylinder exposed. The high-pressure oil then gushes out until the equilibrium of the forces is restored and the communication closed. When the cylinder is empty, the pressure decreases according to the hydraulic properties of the oil. For this reason, the piston always takes up a certain position in the cylinder, determined by the final position of the distribution piston. This position of the piston, in which the ram lies perpendicular to the cylinder surface and thus in the exact line of force, is known as the "working position." Only one of the two torque and thrust pistons are controlled; the others are connected with the pressure space of the first two. The pressure of the thrust piston being lower than that of the torque, all that is needed is a high-pressure conduit which is connected with the distribution piston of the latter.

The high-pressure oil for the thrust piston is obtained from the pressure chamber of a torque piston. The pressure chambers are, moreover, connected by piping with indicators that record directly on a drum the pressures corresponding to the piston forces. The centrifugal forces of piston and oil in the torque, which might obstruct measurements, are obviated by adjusting the center of gravity of the pistons, and by filling the cylinder spaces in front of the pistons with oil. The high-pressure oil conduit from the torque dynamometer to the stationary piping takes place through pipes with plugs. The fixed plug has four bores, into which leads the high-pressure piping, the measurement piping for thrust and torque moment, and a lubrication piping respectively. Grooves are cut to correspond with the torque piping, and these grooves are also connected with the joints of the dynamometer support by piping. The lubrication piping may serve a need as pressure lubrication for the inner bearing surface. The four pipings then pass over a steel bearing block from the plugs and round the torque plane of the propeller to the instrument table for control and use, which is installed in the observer's cockpit (see Figs. 13 & 14, drawing B46). This table bears the pumping installation as well as the recording device, and is mounted on a pneumatic tube to be secure against shocks. It is so contrived that the oil is supplied to the pressure-pump from an oil tank which can be adjusted to the requisite pressure - generally about 40 to 60 kg/cm.^{3} - and is driven by worm gear from the camshaft by means of a pliable shaft, but which can also be manipulated by hand. The oil passes to the pump over an air-chamber in the high-pressure piping built into the oil-tank. By commutation with a three-way cock, the high-pressure oil may be conducted into the torque piping and thus pass directly into the torque cylinder, through the rotation of the distribution piston, at the moment when the high-pressure piping is blocked, thus forcing back the piston until it touches the adjoining piece. Any displacement between the cone and the adjoining piece is thus prevented and the hub becomes entirely rigid. This is called the "LOCKED POSITION." At starting, or when the engine does not run smoothly, the hub is duly closed, as also in gliding flight on short journeys. An extra cock controls the high-pressure oil in the lubrication piping. The recording device consists of a half-hour diagram surface with three indicators. The latter are placed at spaces of 60 mm. round the circumference of the surface of the disc and are of proportional lengths. These spaces must be taken into account in the tracings made by the indicators. Torque, thrust and velocity are recorded, the latter being measured by a pressure plate worked by a piston. A revolution chronometer made on the same principle unfortunately failed in the preliminary tests, though it would have been most useful in establishing precise values by recording torque, thrust, number of revolutions and velocity in one diagram.

After many preliminary aero-mechanical tests had been made at the bench as early as the autumn of 1916, flight tests were made by the D.V.L. and were continued in spring by the FLZ*. They were then set aside for more urgent tests. A year later, they were resumed by the propeller section of the FLZ. with a special airplane and a new D.V.L. hub, when it was intended that propeller investigations should be carried out first of all. The auxiliary instruments as well as the hub were carefully re-calibrated before being installed in the airplane, so that the requisite accuracy of the measuring degrees might be ensured.

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* See EVERLING'S "Temporary Results of Measurements with the Dynamometer Hub," "Technische Berichte," Vol. I, No.2, p.54. These results were confirmed by later measurements by F. Müller, as yet unpublished. See also "The Dynamometer Hub and the Flywheel of the Engine," Zeitsch.f.F.& M. 17/18, p.181. (Translation on file in this office, see Report #5348-15.)

The hub was calibrated at an electric test bench by comparative tests made with thrust and torque moment balance. Torque and thrust are the product of diagram pressure x the transmission factor. The latter is given by the ratio of the indicator and the cylinder openings (see Table 1).

The considerable but constant difference between the torque moment values of hub and balance was due to an error in calibration. The values of thrust were favorable. 1 to 2% insensibility of the test-bench balance must here be taken into account. The pressure disc for measuring velocity was calibrated in the D.V.L. wind-tunnel, by comparing the micronometer and the Pitot tube. A wind velocity of 130 to 140 km/h could be attained. The constant K (see Table 2) was given by the ratio

$h = K.q$

h = height of diagram in mm.

q = dynamic pressure in kg/m^2.

The limit of errors of about 2% in the velocity measurements seems to be extremely high. If 1% be calculated in the measurements of torque, thrust and velocity respectively, as much as 3% can be obtained in calculating the propeller efficiency:

$$C = \frac{0.99 \cdot 0.99\, v}{1.01 \cdot M \cdot n} = 0.97.C\,\frac{P \cdot v}{M \cdot n}$$

P = thrust, M = torque, v = velocity, n = r.p.m.

In estimating propeller performance, especially when various types are being compared, even such an error as this is extremely unpleasant. It is therefore most desirable that the pressure disc itself should be further improved. For the tests, it therefore appeared to be desirable to utilize a second pressure disc in order to obtain the mean values; for want of a fourth indicator, however, it was substituted by a Pitot-tube and an Atmos indicator. The HORN tachometer was finally subjected to re-calibration every fifty revolutions.

The entire testing appliance was then built into a Ru C I airplane with a 160 HP engine (Fig. 13). The Ru C I combines favorable graduation of velocity with good climbing qualities and is therefore most suitable for propeller tests. The chief data are as follows: surface area 38 m.^{2}, span 12.24 m., length 7.91 m., weight in itself 530 kg., measuring hub with auxiliary instruments 60 kg., total weight empty 872 kg., two passengers 150 kg., fuel and oil 170 kg., ballast 30 kg., airplane in flying condition 1224 kg. There was no difficulty about the installation. In laying the piping, sharp curves had to be avoided carefully. The writing drum was installed in the observer's cockpit, secure from shocks and separated from the crankshaft by a second branch of the pump piping, and the pressure disc was secured to the front strut in such a manner that it can turn freely in the wind stream. The equipment was completed by a barometer, three barographs, a gasoline indicator for engine tests, an anemometer for the pilot's observation, a thermometer and signalling apparatus. The lack of equilibrium to the hub was compensated for by 30 kg. ballast in the observer's cockpit.

When functioning in working position, the distribution pistons of the measuring hubs play on the orifices of the borings of the distribution pistons. When the oil is sufficiently thin, this play is particularly noticeable in the torque curve, through the fine oscillations that take place. It is probably also due to the elasticity of the pressure piping and the lack of smoothness of the torque of the engine. These oscillations sometimes increased, - especially in curves or squalls - until the hub struck against the clappet shaft of the hub piece intended for blocking, and caused such shocks to the engine and the airplane that the measurements had to be interrupted by stopping the engine and blocking the piece. With a view to reducing the oscillations, the most smoothly-running engine possible was installed, the propeller was carefully balanced and gauged, and the regularity of pitch was re-measured. A dynamic balancing method would be advisable. The pressure pipings were also carefully ventilated. When the piping of 3 x 4 mm. diameter was finally replaced by piping of 6 x 8 mm., the oscillations ceased almost entirely, while the indicators responded more quickly when the pressure changed. This confirms the supposition that throttling occurs in the thin piping conduits when the hub is subjected to more rapid pressure.

The further development of the tests, especially as regards further difficulties and derangements, can best be seen from tables and roughly drawn diagrams. The first point to be considered is that of obtaining propeller characteristics; that is, thrust and torque should be given in the course of the tests. The conditions of testing were simplified by taking the points of measurement, as far as possible, at uniform altitudes. The thrust of the propeller does not depend upon the position of the airplane in the chamber. The component weights of propeller and hub piece, included in the measurements taken by the dynamometer hub, are of no practical account with a weight of about 20 kg. and when the axis of the engine shaft is in a comparatively slightly transverse position. The curve points of the propeller characteristics can actually be obtained by varying the velocity and the engine power. This was carried out by the pilot at an altitude of about 800 m., when he stated, by means of a signalling device, that the exact velocity of the airplane was 120 km/h. At an altitude of about 1000 m., the diagram showed that a state of equilibrium had been attained. In passing through 1000 m., a measuring point was marked on the diagram and readings of the number of revolutions were simultaneously taken with those of the barometer and thermometer.

At an altitude of about 1200 m., the engine was throttled and the airplane was brought to a constant gliding velocity of 140 km/h. The passage through 1000 m. was marked with another measuring point, and at 800 m., the engine throttle was again fully opened in order that a fresh climb could be made at another velocity. Drawing B46 shows the pressure curves of torque M, of thrust P, and of velocity v, which were simultaneously drawn. The local change of position of the indicators amounts to about 60 mm. in the diagram. When there was a sudden change of conditions, the indicators responded slowly. This inconvenience is especially notceable in the v curves, where the measuring points are but partially utilizable, as they fall between two equilibrium conditions f the curve in the transmission portion.

Derangement in Measuring.

This error was also reduced by the application of further piping and thinner oil. In order to control the adjustment of the indicators and to determine the occurrence of clogging when necessary, the indicators were momentarily connected to the atmosphere at frequent intervals. The effect of this is seen by the recurrence of deep indents in the M curve. Unlike the constant measuring points of the torque moment, the thrust and coefficient of efficiency vary greatly in this case, asin the tablesgiven further on. A thorough investigation proved that there was clogging on the bearing surfaces of the hub and cone pieces. The frictional forces were added to the propeller thrust in the readings given by the hub, with the result that the thrust and coefficient of efficiency given were too high. It is anything but easy to grind in the piston so as to avoid friction, due either to slight deformation of the hub flange on account of the unequalized thrust of the propeller bolts or to expansion of the wooden hub due to changes of weather, and to insure, at the same time, the safe guidance of the propeller shaft. Similar clogging also occurs in the cylinder

The pistons, tightly fitted in on account of the high working pressure , are especially liable to seizure by reason of their short oscillating motion. This friction is clearly shown by the M curves in test No. 8. The pistons were therefore ground in less tightly, and increased loss of oil was taken into account. Test 12 (see drawing B46) was intended to prove the decrease of torque and thrust with atmospheric pressure at constant flight velocity, and to show the exactitude of the measurements by the constancy coefficient of the measuring points. The tests could be executed at an average velocity of 115 km/h. Assuming that there is a lineal function up to that altitude, the measurements of torque moment show mean deviations of ± 2 to 3%. Test No.17 also shows a constant decrease of torque with atmospheric pressure. The thrust values are all too high. As a new engine was used, - the third since the commencement of the flights - the measuring points are compared with those of Test No. 12. After renewed overhauling of the dynamometer, Tests 19 and 20 resulted in a series of measuring points at a similar altitude, at similar velocities. The torque moments coincide satisfactorily, but the thrust and efficiency are again too high.

A second dynamometer was then procured, specially intended for engine tests and similarly installed in a Ru C I airplane. The derangements above described also occurred in this instance, though better thrust values were obtained. The test airplane, which was unfortunately strongly influenced by the frequent oscillations and repeated mounting and dismounting of the engines, was replaced at the same time by two new Ru C I airplanes with reinforced carriage, elastic engine bedding and a spacious cockpit for the observer. One of these airplanes was to be equipped with a 180 HP B.M.W. engine for altitude tests, an altitude of 3000 m. being the highest possible maximum for the old airplane, due to the inferior quality f engine fuel then available. As soon asthe dynamometer was installed, the tests emerged from the long preliminary stage and ere developed into systematic and useful measurements. About 30 itilizable test tables had been obtained by this means before the utbreak of the War, which put an end to further investigations.

Many objections to the dynamometer have been raised by people who based their opinion on the obvious inaccuracy of the measurements taken in early tests, and also on the lack of systematic test results after comparatively long testing activities. This latter omission was due to the fact that the Board of Aviation was overwhelmed with other and more urgent work for the front. The exactitude of about ± 1% for torque measurements, as shown by the tables, is quite adequate for engine tests.

The error limit in thrust and velocity measurements can be reduced to considerably less than the ± 2% so far attained, when the results that have been obtained can be applied. The preliminary conditions needed for the perfect functioning of the dynamometer may be classed under the following main headings:

1. Correct bearing clearance between the hub-piece and the cone-piece and the dynamometer/piston, with frequent control of same.
2. Frequent controlling of the indicators and their springs.
3. Suitable viscosity of the oil under various weather conditions.
4. Rigorous protection from dust of the organs of the dynamometer and oil pipings.

[illegible]

Taken as a whole, the tests prove that though the dynamometer is a sensitive measuring instrument liable to numerous derangements it is undeniably useful even in its present form, when handled with care and skill. Facilitating, as it does, the possibility of maintaining the fixed position of the engine, the blocking out of the weight effect when the airplane is in a sloping position, and the possibility of taking direct measurements of force at the point of transmission, the dynamometer appears to be by far the best solution of the problem of a flying test-bench, utilized as a hydraulic balance with the smallest possible measuring stroke and the least tendency to oscillation. It is therefore most desirable that further investigations should be made in this direction.

(Translated by the Paris Office, N. A. C. A.)

Table 1.

Dynamometer Hub No. 4,

Ru CI 8367, Flz.

Calibration at the Electric Propeller Test-Bench. (15/4/18)

No.	Torque Moment			
	Test-bench balance M in kg/m.	Indicator		Errors in %
		p in kg/cm²	M in kg/m	
1	80	19.6	77.5	-3.0
2	70	16.8	66.5	-4.8
3	60	14.4	57.0	-4.8
4	50	11.9	47.0	-5.8
5	40	9.6	38.0	-5.0
6	30	7.5	29.7	-1.0
7	80	19.5	77.5	-3.2
8	70	16.8	66.5	-4.8
9	60	14.4	57.0	-4.8
10	70	16.7	66.5	-4.8

No.	Thrust				Remarks
	Test-bench balance P in kg.	Indicator		Errors in %	
		p kgm/cm.²	P in kg.		
1	-	-	Springs	-	Graduation
2	-	-	too weak	-	of springs
3	330	13.5	340	+3.0	fM=2mm.
4	274	10.8	270	-1.3	fP=4mm.
5	221	8.8	220	-0.3	
6	170	6.6	165	-2.8	
7	426	16.9	425	-0.2	
8	376	15.0	376	0	fP = 3 mm.
9	326	13.1	330	+1.2	
10	375	15.0	376	+0.2	

Table 2.

Pressure Disc No. 1. Calibration in the Wind-Tunnel.

Test	Mean pressure due to velocity	Ordinate read on the diagram: h in mm.	Constant k = h/q	Deviation from mean value in %	Deviations of velocity in %.
1	14.25	6.5	0.456	-7.1	-2.7
2	24.60	12.3	0.500	+1.2	+1.1
3	32.10	15.2	0.474	-3.7	-1.9
4	45.50	23.3	0.491	-0.4	-0.6
5	55.00	27.5	0.500	+1.3	+1.1
6	66.1	31.6	0.478	-3.0	-1.7
7	67.8	35.0	0.517	+4.7	+2.17
8	85.5	43.0	0.503	+2.0	+1.4
9	32.1	16.0	0.498	+1.2	+1.1
10	54.2	27.8	0.514	+4.2	+2.1

Table 3. **

Dynamometer Hub Test No. 3. Ru C I 4167. Wolff Propeller No.1105.

No. of reading	Specific Gravity of the air $\gamma=kg/m^3$	Torque M=kgm.	Thrust P = kg	Flying Velocity v=km/h	r.p.m. n/min	Engine power N_M=HP	Flight efficiency N_F=HP	Propeller efficiency η = %
1	1.220	85.6	297	125	1380	165	137	84
2	1.253	81.6*	292	124	1375	157*	134	86*
3	1.213	84.5	294	123	1395	165	134	81
4	1.206	82.8	288	131	1400	162	140	86
5	1.185	79.7	272	116	1355	151	117	77
6	1.185	76.0	264*	159*	1480	157	156*	99*
7	1.185	79.3	260	125	1380	153	120	78
8	1.197	76.5	249	122	1370	146	113	77
9	1.190	75.7	254	148*	1450	153	139*	91*
10	1.191	76.5	256	130	1400	149	123	82
11	1.202	76.5	259	128	1430	153	123	80

** Test 2. 18. 19. (See Drawing B 45)

* Derangement in measuring.

T a b l e 4. **

Measuring Hub Test No.12. Ru C I 4167. Wotan Propeller No.3640.

No. Reading	Specific Gravity of air γ =kg/m³	Torque M=kg/m	Thrust P=kg	Flying Velocity v=km/h	r.p.m. n/min.	Engine power N_M=HP	Flight efficiency N_F = HP	Propeller efficiency η = %
1	1.188	73	272	119	1440	147	120	82
2	1.165	72	278	118	1440	145	121	84
3	1.130	68	265	118	1430	136	116	86
4	1.097	67	260	118	1430	134	114	85
5	1.082	66	261	115	1430	132	111	85
6	1.053	64	260	115	1440*	128*	111	87*
7	1.041	63	258	115	1440*	126*	110	88*
8	1.007	62	240	115	-	-	102	-
9	0.993	59	245	115	1440*	118*	104	89*
10	0.971	58	235	114	-	-	99	-
11	0.967	57.5	230	113	-	-	96	-

** Test 5. 29. 18. (see Drawing B-45)

* Approximately (r.p.m. varies greatly).

T a b l e 5.***

Dynamometer Test No.17. Ru C I 4167. Wotan Propeller 3640.

No. Readings	Specific Gravity of air γ =kg/m³	Torque M=kg/m	Thrust P=kg	Flying Velocity v=km/h	r.p.m. n/min	Engine power N_M=HP	Flight efficiency N_F = HP	Propeller efficiency η = %
1	1.124	66	260	129	1440	133	124	All
2	1.120	64	265	124	1430	128	121	the
3	1.060	62	260	126	1430*	124	121	thrust
4	1.031	60	247	125	1430*	120*	115	values
5	1.020	59	237	134	1440	129	117	are
6	1.021	58	230	143**	1470*	119*	122**	too
7	1.022	58	226	143**	1470*	119*	120**	high.
8	1.013	59	242	127	1430*	118*	114	-

*** Test 6. 13. 18. (See Drawing B-45)

** Derangement in measuring.

* Approximately.

Table 6.**

Dynamometer Test No.19. Ru C I 4167. Wotan Propeller No.3640.

No. of Reading	Specific Gravity of air γ = kg/m³	Torque M=kg/m	Thrust P = kg	Flying Velocity v=km/h	r.p.m. n/min.	Engine power N_M=HP	Flight efficiency N_F = HP	Propeller efficiency η = %
1	1.092	70.1	279	115	1420	139	118	85
2	1.102	38.8	100	137	1250	68	51	75
3	1.098	71.2	268	124	1425	142	122	86
4	1.102	40.8	105	137	1240	71	53	76
5	1.098	71.2	259	131	1450	144	126	88
6	1.085	70.6	257	132	1450	143	125	88
7	1.092	71.2	251	143	1475	147	133	91
8	1.098	70.6	276	115*	1420	146	117*	84*
9	1.098	41.6	120	137	1240	72	61	85

**Test 7. 12. 18. (See Drawing B-45).

* Derangement im measuring.

NOTE: Nos. 1, 3, 5, 7, and 8 were flown with full intake.
Nos. 2, 4, and 9 were flown with gasthrottled down.

Table 7.**

Dynamometer Test No.20. Ru C I 4167. Wotan Propeller No. 3640.

No. of Reading.	Specific Gravity of air γ = kg/m³	Torque M=kg/m	Thrust P=kg.	Flying Veloc- v=km/h	r.p.m. n/min	Engine Power N_M =HP	Flight efficiency N_F =HP	Propeller efficiency η = %
1	1.095	68.1	282	127	1480	141	133	92
2	1.070	67.7	282	127	1480	140	133	92
3	1.100	40.4	131	143	1280	72	70	97
4	1.100	70.5	282	129	1480	146	130	89
5	1.070	67.4	277	128	1480	139	131	94
6	1.102	39.6	125	145	1290	71	67	94
7	1.100	68.5	282	130	1480	147	136	93
8	1.102	39.2	131	146*	1280	70	71*	-

** Test 13. 7. 18. (See Drawing B-46).

* Derangement in measuring.

NOTE: Nos. 1, 2, 4, 5 and 7 were flown with full intake.
Nos. 3, 6 and 8 were flown with gas throttled down.

CHIEF ELEMENTS OF THE DYNAMOMETER HUB.

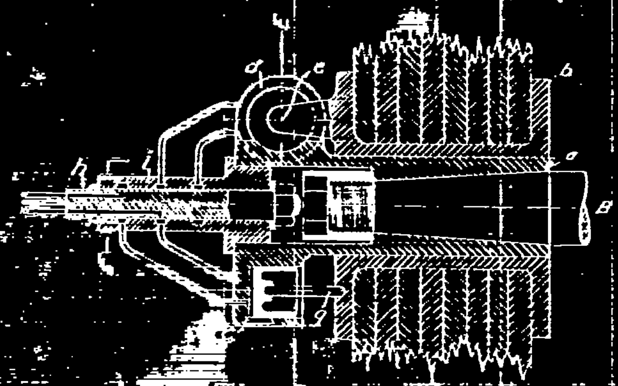


Fig. 2.

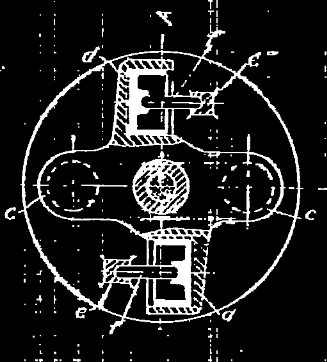


Fig. 3.

ASSEMBLY DRAWING OF THE DYNAMOMETER HUB.

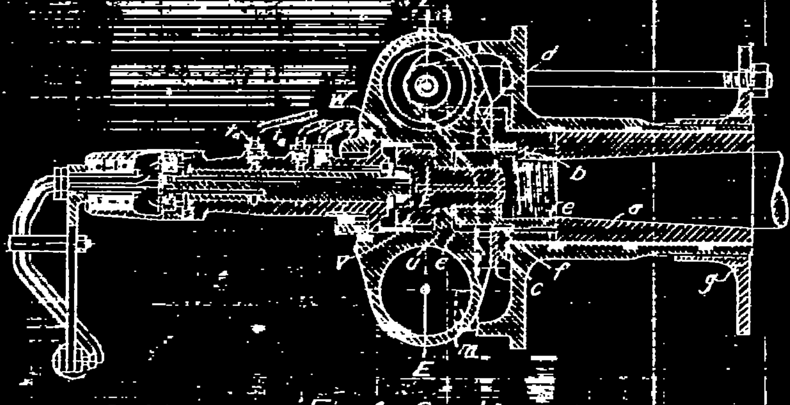


Fig. 4. Section A-B.

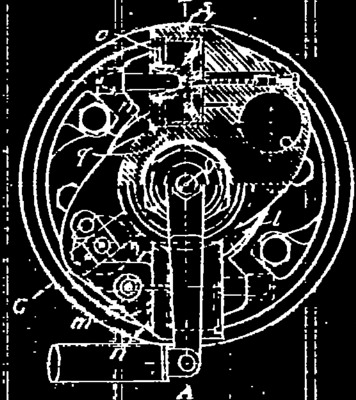


Fig. 6 Section E-F.

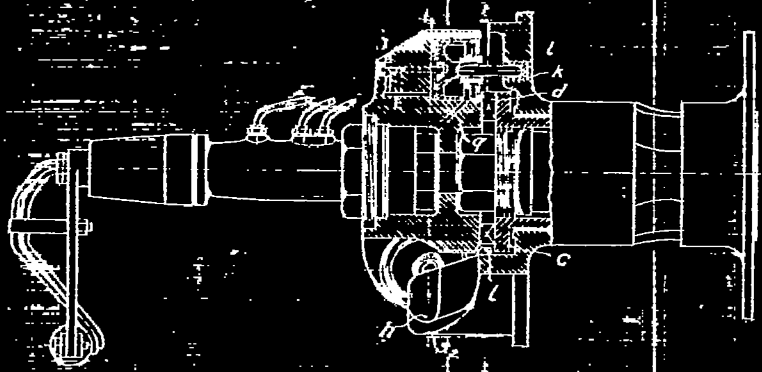


Fig. 5. Section C-D.

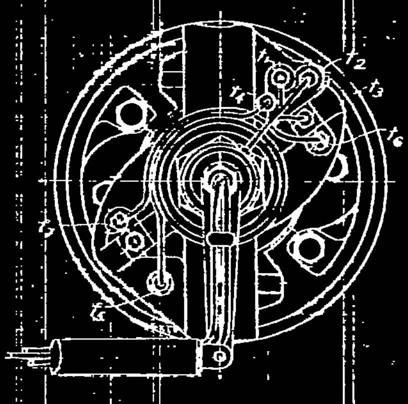


Fig. 7.

Figs. 2-3-4-5-6-& 7.

Load balancing device of Prof. Bendemann.

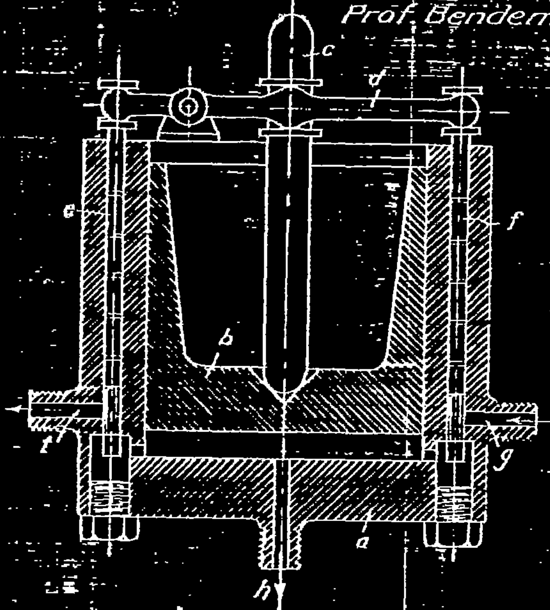


Fig. 1.

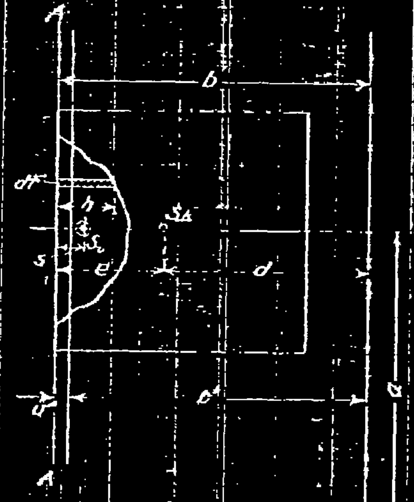
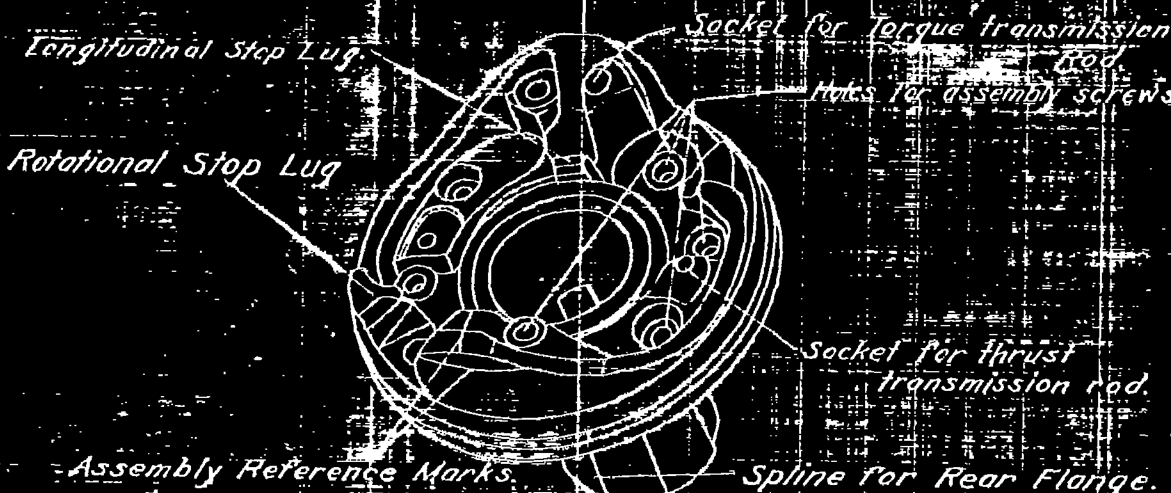


Fig. 9.



Complete Hub Piece.
Fig. 8.

Figs. 1-8-&9.

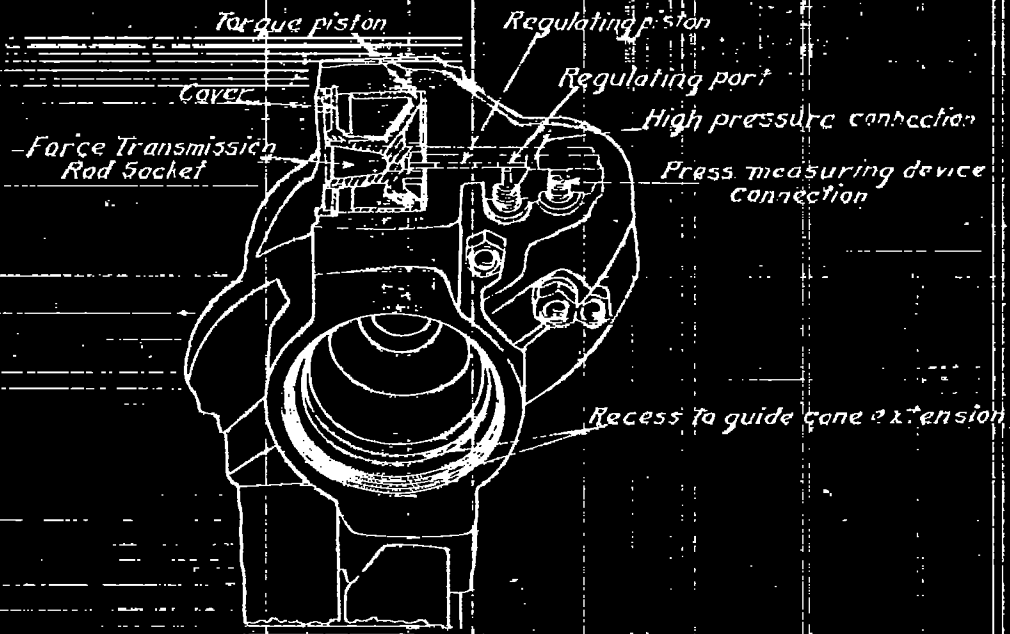


Fig. 10.

Section thru Torque Measuring Device showing regulating parts.

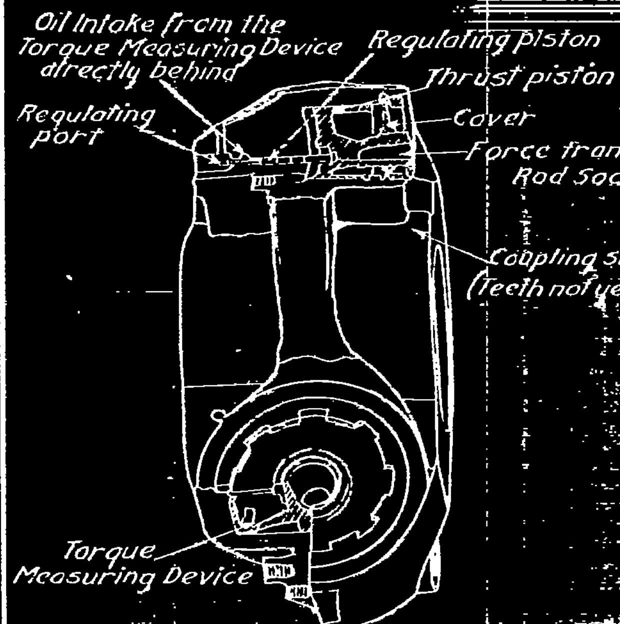


Fig. 11.

Section thru Thrust Measuring Device showing regulating parts.

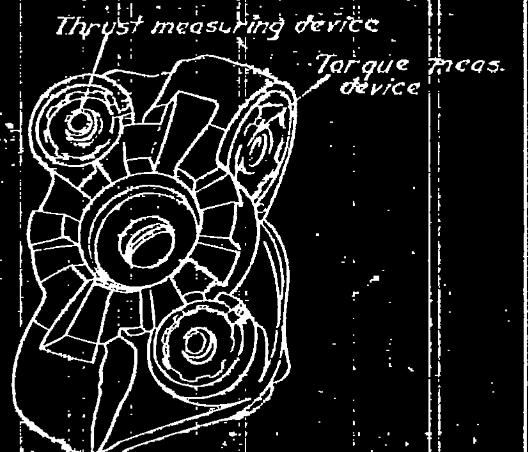


Fig. 12.
Coupling Side

DYNAMOMETER DEVICE SUPPORT

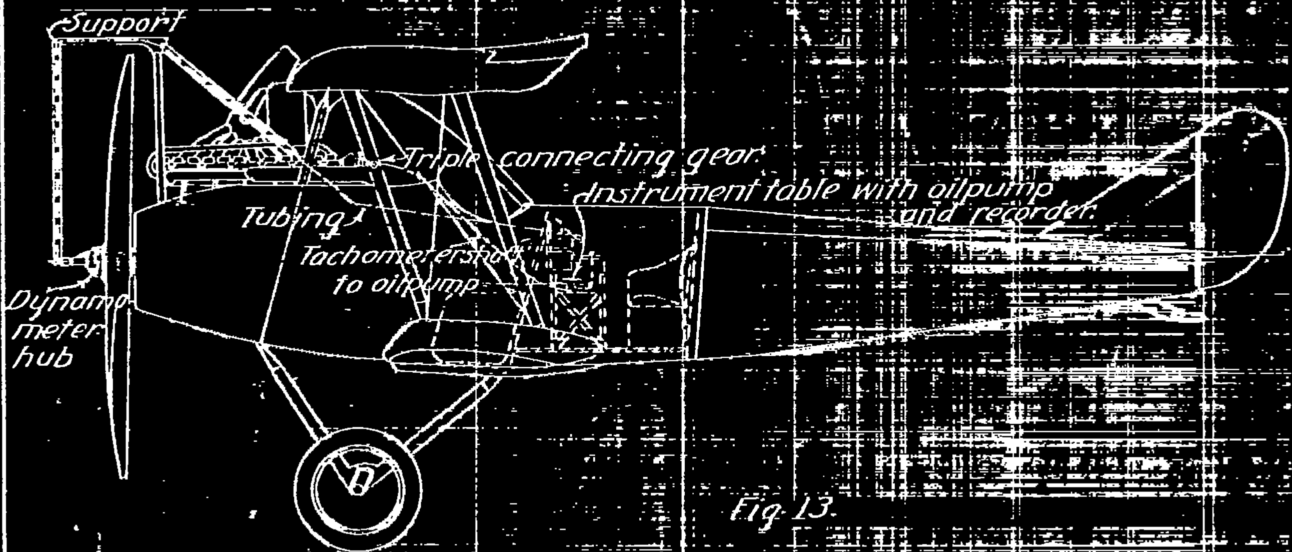


Fig. 13.

Assembly of apparatus showing connection for dynamometer hub.

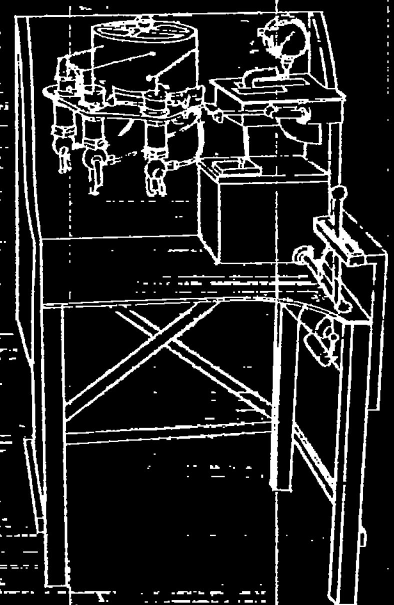
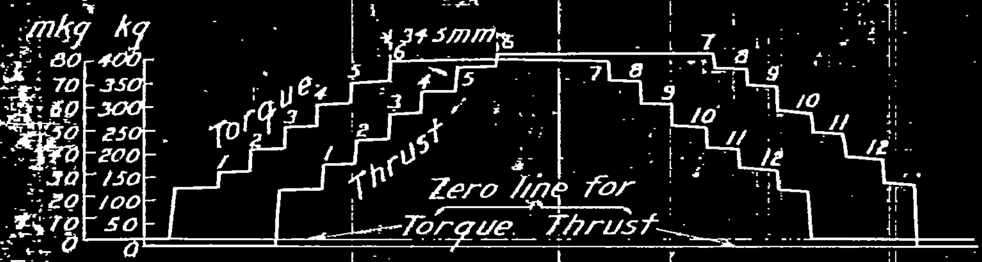


Fig. 14.

Instrument table.

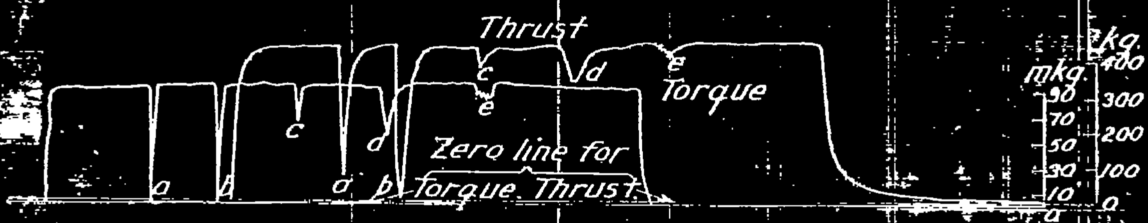
Figs. 13 and 14.

Fig. 15.



Calibration of the Dynamometer Hub

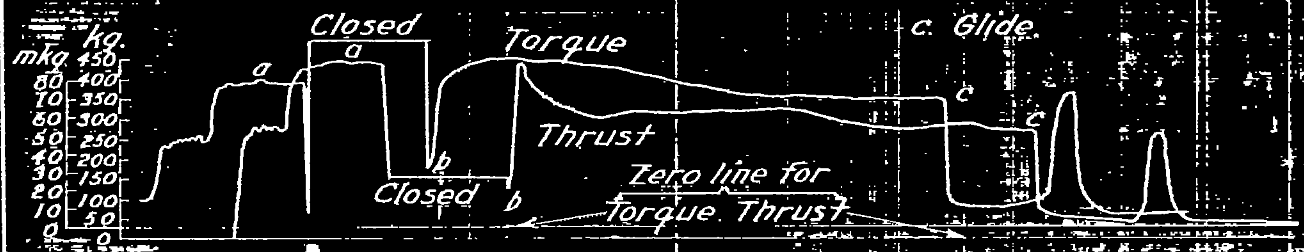
Fig. 16.



Full load diagram of the Dynamometer Hub.

a. Static test with full load.
b. Start.
c. Glide.

Fig. 17.



Record of the first flight.

Fig. 18.

Free flight test in gusty weather.

O. ENOCH. THE DYNAMOMETER HUB FOR TESTING PROPELLERS AND ENGINES DURING FLIGHT

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS PARIS OFFICE

DESIGNED
DRAWN
CHECKED W. K.
APPROVED W. K.

B 45

5345-3

O. ENOCH, THE DYNAMOMETER HUB FOR TESTING PROPELLERS AND ENGINES DURING FLIGHT

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS PARIS OFFICE

DES.
DRAWN 12-18-17
CHEKED
APPROVED W. K.

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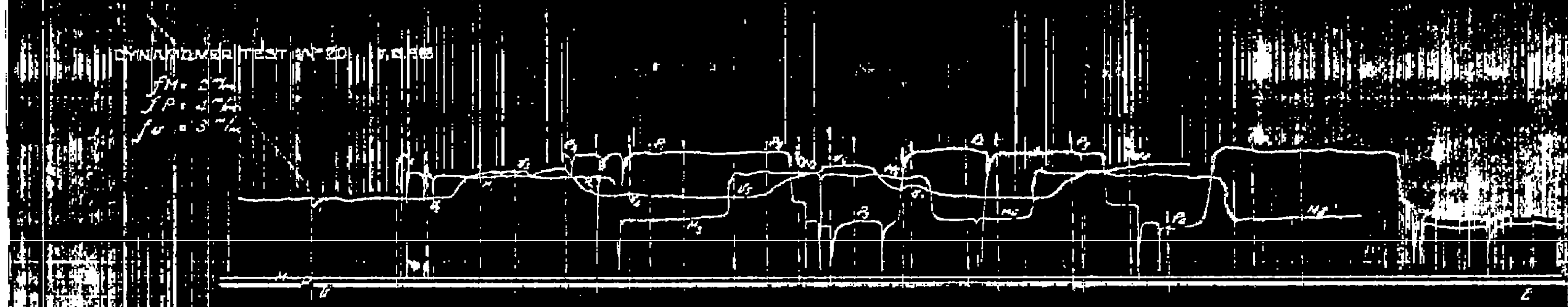

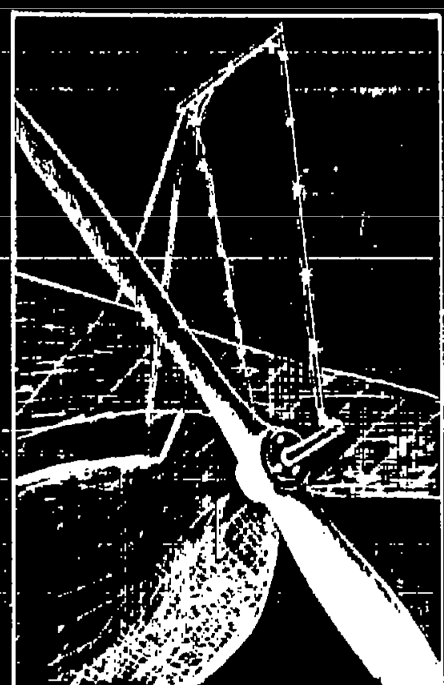

Dynamometer viewed from the front of the airplane. The manometric capsule and the piping with connecting tubes are clearly recognizable.